International Journal of Agricultural
Science and Research (IJASR)
ISSN(P): 2250-0057; ISSN(E): 2321-0087
Vol. 7, Issue 5, Oct 2017, 521-530

APPLICATION OF RS AND GIS TECHNIQUES IN THE ANALYSIS OF MORPHOMETRIC CHARACTERISTICS OF UPPER BERACH RIVER BASIN, RAJASTHAN STATE

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ABSTRACT

Natural resource conservation and its sustainable planning and development of a river basin can be done satisfactory by morphometric characteristics analysis. In the present study, Survey of India toposheets no. 45H/9, 45H/10, 45H/13, 45H/14, 45L/1 and 45L/2, were used to evaluate hydro morphometric characteristics (viz. Linear, aerial and relief) of Upper Berach river basin in GIS environment using the ARC GIS 10.1 software. Results reveals that the total area of river basin covers 1095.98 km2, which divided in two sub-basins, covers the area of 431.08 and 664.90 km² respectively. Dendritic to sub-dendritic drainage pattern with stream orders of sub-basins, are found with ranged from VI to VII orders. Sub-basin stream length ratios are changing haphazardly which is indicating differences in slope and topographic conditions. Mean bifurcation ratio values vary from 3.28 to 4.13. Drainage density shows variation from 1.77 to 1.84 km/km² in the whole river basin and sub-basins. The values of form factor and circularity ratio are varied from 0.15 to 0.23 and 0.24 to 0.47, in the whole river basin and sub-basins The ruggedness number of river basins, sub-basin-1 and sub-basin-2 are 0.83, 0.40 and 0.83.

KEYWORDS: Morphometric Analysis, Upper Berach River Basin, Remote Sensing & GIS Techniques

Received: Sep 18, 2017; **Accepted:** Oct 07, 2017; **Published:** Oct 13, 2017; **Paper Id.:** IJASROCT201760

Original Article

INTRODUCTION

Geo morphological parameters directly or indirectly reflect almost the entire watershed based causative factors affecting runoff and sediment loss. Geomorphic parameter study is a tool for prediction of hydrologic behavior of a basin. The Morphometric characteristics study is an important aspect, for the characterization of watersheds (Strahler, 1964). Mathematical analysis of the earth's surface, shape and dimension of its landforms could be achieved through measurement of linear, aerial and relief aspects of basin and slope contributions (Nag and Chakraborty, 2003; Putty, 2007). The Morphometric characteristics study includes the measurement of linear features, aerial aspects, relief aspects of the drainage basin (Dhabale *et al*., 2014; Dahipale *et al.,* 2016). Linear aspects study involves a measurement of stream order (u), stream number (N_u), bifurcation ratio (R_b), stream lengths (L_u), stream length ratio (R_L), etc. Aerial aspects study involves the measurement of drainage density (D_d), texture ratio, stream frequency, form factor (R_f), circularity ratio (R_c), elongation ratio (R_e) and length of overland flow etc. The relief aspects study involves measurements of relief ratio (R_r), Relative relief (R_R) and ruggedness number (R_N) Main stream channel slope (S_c) etc. Drainage characteristics study of many river basins and sub basins in different parts of the globe have used conventional methods (Horton 1945; Strahler 1964;

Morisawa 1959; Krishnamurthy et al. 1996). RS and GIS technique has emerged as a powerful tool, for morphometric analysis in recent years. Remote sensing technique was applied on morphometric analysis of watershed in recent year, on some part of india (Suryawanshi and Desai (2014); Saha and Mukhopadhyay (2015) and Gavit et al. (2016). Taking consideration of morphometric parameters necessitates and analysis of various drainage parameters,r such as ordering of the various streams, measurement of basin area and perimeter, length of drainage channels, form factor, stream frequency, circulatory ratio, drainage density, length of overland flow, bifurcation ratio, basin relief, relief ratio, ruggedness number etc, a study was undertaken, with the objective to compute geo morphological parameters of Upper Berach basin, using remote sensing and geographical information system technique.

MATERIALS AND METHODS

The upper Upper Berach is a river flowing through the state of Rajasthan, in the western part of Rajasthan. It lies on the western part of India between the latitudes of $24^0 33'37.75''$ to $24^0 56'36.532''$ N and the longitudes of $73^0 38'6.256''$ to $74^0 5'33.104''$ E. In this study, the Upper Berach River originates in the hills of Udaipur and Rajasmand districts. River basin was divided into two sub-basins. The total catchments area of the basin is 1095.98 km^2. The area is characterized by sub-humid climate, with an average annual rainfall of 630 mm. The general topography of the area is hilly and undulating.

In the present study, Survey of India toposheets was used to prepare basin boundary and drainage network, in GIS environment. Figure.1 shows the digitized boundary and stream network. Delineated drainage pattern for basin and two sub-basins were exported to ARC/INFO 10.1 for Geo morphometric analysis. The aerial, linear and relief aspect parameters computed by standard methods (Table 1). Area, perimeter, elevation, stream number, maximum stream length, stream length of each order etc were derived from the digitized drainage network map in GIS environment.

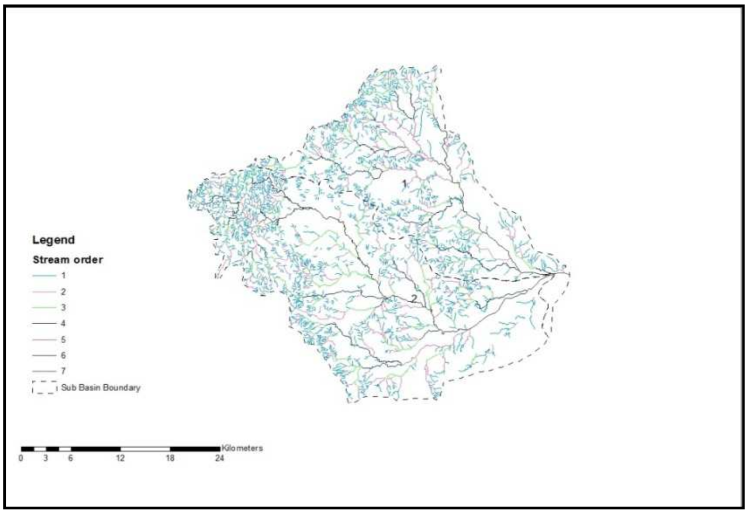

Figure 1: Drainage Map of Upper Berach River Basin

Table 1: Morphometric Parameters Computation Formulae

S. No.	Parameters	Formula/Symbol	Reference
1.	Stream order (u)	Hierarchical rank	Horton (1945)
2.	Stream length (L_u)	Length of stream	Horton (1945)
3.	Mean stream length (L_{sm})	$L_{sm} = L_u / N_u$ L_{sm} =Mean stream length (km) L_u =Number of stream length of order 'u', N_u=Number of stream of order 'u'	Strahler (1964)
4.	Bifurcation ratio (R_b)	$R_b = N_u / N_{u+1}$ N_u = No of streams of order u, N_{u+1} = No of streams of order u+1	Schumn (1956)
5.	Mean bifurcation ratio (R_{bm})	R_{bm} = Average of bifurcation ratio of all orders.	Strahler (1964)
6.	Drainage density (D_d)	$D_d = L_u / A$ A = Basin area (km ^{2})	Horton (1945)
7.	Stream frequency (F_s)	$F_s = \Sigma N_u / A$ A = Basin area (km ^{2})	Horton (1945)
8.	Form factor (F_f)	$F_f = A / L_b{}^2$ F_f=Form factor, A=Area of the basin (km ^{2}), L_b=Basin length (km)	Horton (1945)
9.	Circularity ratio (R_c)	$R_c = A/A_C = 4 \pi A / P^2$ A_C = Area of circle having equal perimeter as the perimeter of watershed (km ^{2}), P = Perimeter of basin (km)	Miller (1953)
10.	Elongation ratio (R_e)	$R_e = (2 / L_b) * (A / \pi)^{0.5}$	Schumn (1956)
11.	Length of overland flow (Lg)	$Lg=I/D_d*2$ L =Length of overland flow D_d =Drainage density	Horton (1945)
12.	Constant Charnel Maintenance (C)	$C=-I/D_d$ C=Constant of channel maintenance D_d =Drainage density	Schumn (1956)
13.	Relief (H)	Elevation of basin mouth) - (Elevation of highest point on the basin perimeter)	
14.	Relief ratio (R_r)	$R_r = H/L_b$ H = Watershed relief, L_b = Main stream length (km)	Schumn (1956)
15.	Ruggedness number (R_N)	$R_N = H \times D_d$ H=Basin relief, D_d =Drainage density	Strahler (1952)

RESULTS AND DISCUSSIONS

Linear Aspects of Basin and Sub-Basin

The linear aspects of the basin such as stream order, stream length, number of stream length, length ratio and bifurcation ratio were computed in GIS environment using ARC/Info 10.1 software and given in Table 2 (a & b).

Stream Order (u)

Strahler (1964) has proposed a method for ranking of streams. According this method, on branched fingertip streams are designated as 1st order, the confluence of two 1st order channels give 2nd order stream and two 2nd order streams give 3rd order and so on. In the present study, drainage pattern is dendrite. Sub-basin-2 has a sixth order stream and sub-basin-1 has a seventh order stream. Total stream number in sub-basin-1 and sub-basin-2 are 1024 and 1496. Stream

frequency decreases as the stream order increases.

Stream Length

Stream length of various orders in both sub-basins was computed on a digitized map, in GIS environment. It was observed that, the stream length decreases as the stream order increases. The total stream length of the Upper Bearch river basin, sub-basin-1 and sun-basin-2 are 1959.77 km, 782.29 and 1177.48 (Table 2a).

Stream Length Ratio (R_L)

It was found that, the stream length ratio changing haphazardly in a basin and sub-basins. The values of the stream length ratio (R_L) in the Upper Bearch river basin, sub-basin-1 and sub-basin-2 vary from 0.05 to 4.84, 0.15 to 2.96 and 1.29 to 8.05 (Table 2b). It is revealed that, the stream length ratio of different order shows variation, due to differences in slope and topographic conditions (Sreedevi et al. 2005).

Mean Stream Length

As per Strahler (1964) Mean stream length is a ratio of the total length of stream in each order, to total no of each order. It is characteristic property, which is interrelated to the drainage network and its surrounding surface. Its value varies in whole basin, sub-basin-1 and subbasin-2 from 0.57 to 12.44, 0.56 to 53.64 and 0.56 to 39.26.

Bifurcation Ratio (R_b)

Schumn (1956) defined the ratio of the stream number of one order to next higher orders. It is also called shape factor. The values of the bifurcation ratio vary from 1.5 to 3.72 and 3.0 to 5.33 in sub-basin-1 and sub-basin-2 respectively, while its values vary between 2.0 to 4.5 consider as whole basin. The lowest and highest value of the bifurcation ratio was found in sub basin-1. It was also observed that bifurcation value is not identical for different order stream. Low bifurcation value (R_b) indicates elongated basin and High bifurcation value (R_b) indicates circular basin (Morisawa, 1985). In this study area, the higher values of R_b indicate a strong structural control in the drainage pattern, whereas the lower values indicate that the sub-basins are less affected by structural disturbances (Stahler, 1964; Vittala *et al.*, 2004, Chopra *et al.*, 2005 and Dahipale *et al.*, 2016). The mean bifurcation ratio values are 3.28 and 4.13 for sub basin-1 and sub-basin-2 and 3.64, for Upper Bearch river basin, which are falling under the normal category (Strahler 1957).

Stream Number and Stream Order Relationship

Horton's (1945) laws of stream numbers states that the number of stream segments of each order form an inverse geometric sequence with plotted against order, most drainage networks show a linear relationship with small deviation from a straight line. From the Fig.3, the plotting of logarithm stream number (ordinate) against stream order (abscissa) gives a straight line and satisfying the Hortons law (Kumar *et al.*, 2001). This means that, the number of streams usually decreases in geometric progression as the stream order increases.

Stream Length and Stream Order Relationship

In the present study, it was observed that logarithm plotting of the cumulative stream length (ordinate) against stream order (abscissa) has a linear relationship with small deviation from a straight line (Fig.4). The straight-line indicates that the ratio between cumulative length and order is constant throughout the successive orders of a basin and suggests that geometrical similarity is preserved in basins of increasing order (Kumar et al., 2001; Gupta, 2003, and Dhabale *et al.*,

2014).

AERIAL ASPECTS OF BASIN

It is the two dimensional study of the river basin. This study includes the computation of drainage density, stream, frequency, elongation ratio, circularity ratio, the form factor of basin and their computation is presented in Table 3. The drainage area of the Upper Berach River, sub-basin-1 and sub-basin-2 are 1095.98 km^2, 431.08 and 664.90, respectively.

Drainage Density (D_d)

Drainage density expressed as the stream length of all orders per drainage area (Horton1932). Drainage density of the whole basin, sub-basin-1 and sub-basin-2 are 1.79, 1.84 and 1.77 km/km^2. The drainage density values for whole basin, sub-basin-1 and sub-basin-2 are below 3, which indicate that, the fissured and jointed rock strata are relatively permeable, a characteristic feature of coarse drainage. Drainage density is affected by Lithology, land use, infiltration precipitation intensity, soil characteristics, relief human activity and stage of drainage network development. The basin has high runoff producing potential as it has high relief and higher value of drainage density.

Stream Frequency (F_s)

It is the ratio of the total number of stream segments per drainage area (Horton1932). It is also called drainage frequency or channel frequency. Lithology and texture of the drainage network influence the stream frequency. The stream, frequency value of the whole basin, sub-basin-1 and sub-basin-2 are 2.27, 2.38 and 2.21 respectively. It is also seen that the stream, frequency values of the sub-basins exhibits a positive correlation with the drainage density and suggesting that there is an increase in stream population with respect to increasing drainage density. Generally, High value of stream, frequency (F_s) is related to low permeability, high runoff, high relief conditions and low infiltration capacity (Reddy et al. 2004).

Form Factor (F_f)

According to Horton (1945), form factor predicts the flow intensity of the basin of a defined area. It is the ratio of area of the basin in the square of basin length. There is a direct relationship of form factor with peak discharge. Low form factor indicates elongated basin shape. The basin of high form factor has a peak flow for shorter duration. The value of form factor would always be greater than 0.78 for a perfectly circular basin. Form Factor (F_f) values of the whole basin, sub-basin-1 and sub-basin-2 are 0.23, 0.18 and 0.15 respectively which indicate that they are sub-circular and elongated in shape. Flood flows of elongated basins are easier to manage than the circular basin (Nautiyal, 1994).

Circularity Ratio (R_c)

According Miller (1953), it is the ratio of the basin area to circle area, having same circumference as the basin perimeter. Lithology of the basin affects the circularity ratio. Circularity ratio values of the whole basin, sub-basin-1 and sub-basin-2 are 0.50, 0.30 and 0.40, respectively. A value near to one means more circular shape and it gets scope for uniform infiltration and takes long time to reach excess water at basin outlet, which further depends on the prevalent geology, slope and land cover (Strahler, 1964).

Elongation Ratio (R_e)

According to Schumm (1956), it is the ratio of the diameter of the circle of the same area, as the basin area to the

maximum basin length. The elongation ration of basin can be grouped as circular (>0.9), oval (0.8-0.9), less elongated (0.7-0.8), elongated (0.5-0.7) and more elongated (<0.5) (Strahler, 1968). The elongation ratio of the whole basin, sub-basin-1 and sub-basin-2 are 0.54, 0.47 and 0.44, respectively, which indicate that, whole basin has elongated shape and other sub-basins have a more elongated shape. (Strahler, 1968).

Constant of Channel Maintenance (C)

According to Schumm (1956), it used the inverse of drainage density having the dimension of length. Rock type, permeability, climatic regime, vegetation cover as well as duration of erosion affect the constant of channel maintenance. The value of constant of channel maintenance for whole basin, sub-basin-1 and sub-basin-2 are 0.569, 0.551 and 0.565 respectively. It indicates that these basins and sub-basins are under the influence of high structural disturbance, low permeability, steeps to very steep slopes and high surface runoff. Near the value of 0.5 indicate less soil depth and more erosion from the surface with a high steep slope.

Length of Overland Flow (Lg)

According to Horton (1945), it is the length of water over the ground surface before it gets concentrated into definite stream channels. It is approximately equal to half of the reciprocal of drainage density. The length of overland flow (Lg) is one of the most important independent variables, affecting both the hydrological and physiographical development of the drainage basins (Horton 1945). The computed value of L_g for whole basin, sub-basin-1 and sub-basin-2 are 0.280, 0.276 and 0.282 km^2/km, respectively.

RELIEF ASPECTS OF BASIN

The relief aspects of the basin include the computation of relief, relief ratio and ruggedness number (R_N) and presented in Table 4. Drainage development, surface and sub-surface water flow, permeability, landform development and associated features of the terrain are affected by relief aspect. The maximum height and lowest height of the whole basin, sub-basin-1 and sub-basin-2 are is 920, 672 and 920 m and 454, 454 and 469 m respectively.

Relief (H)

It is can be defined as the maximum vertical distance between the lowest and the highest points of a basin (Schumm, 1956). The value of relief for Upper Bearch basin, sub–basin-1 and sub–basin-2 are 466, 218 and 451 m, respectively. The high relief value indicates the gravity water flow, low infiltration and high runoff, in the basin area.

Relief Ratio (R_r)

According Schumm (1956), it is the ratio of the total relief of the basin, to the longest dimension of the basin, parallel to the main drainage line. The relief ratio increases, as drainage area decreases and the size of the watersheds of a given drainage basin. The relief ratio of the basin, sub-basins-1 and sub-basins-2 are 0.0068, 0.005 and 0.008, respectively. The relief ratio of the basin as well as the sub-basins of the study area is low, which are characteristic features of less resistant rocks of the area (Sreedevi, 1999).

Ruggedness Number, R_N

To combine the qualities of slope steepness and length, a dimensionless ruggedness number (R_N) is defined as the product of relief (H) and drainage density (D_d), where both terms are in the same unit (Strahler, 1952). Extremely high

values of the ruggedness number occur, when both variables are large, that is when slopes are not only steep but long as well. The value ruggedness number of Upper Bearch river basin, sub–basin-1 and sub-basin-2 are 0.83, 0.40 and 0.80, respectively, which indicate, Upper Bearch river basin and sub-basin-2 have sharp morphology and sub-basin-1 has slight morphology

CONCLUSIONS

Morphometric analysis of the Upper Bearch river basin, using remote sensing and geographical information system has great importance parameters, for river basin evaluation and natural resources management. The Upper Bearch river basin has two sub-basins viz. sub-basin-1 and 2. The maximum stream, frequency is found in first order streams and there is decreased, as the stream order increases. The total stream length of the study area is 1959.77 km. The mean bifurcation ratio of the study area varies from 3.28 to 4.13 indicating that all the basins are falling under normal basin category. The Drainage density of the whole basin, sub- indicating the fissured and jointed rock strata are relatively permeable, a characteristic feature of coarse drainage. Form Factor (F_f) values indicate that they are sub-circular and elongated in shape. Constant of channel maintenance indicating that these basins and sub-basins are under the influence of high structural disturbance, low permeability, steeps to very steep slopes and high surface runoff. Gravity water flow, low infiltration and high runoff in the basin area have occurred due to the high value of relief.

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Table 2(a): Linear Aspects of Upper Bearch River Sub-Basins

Basin/ Sub-Basin	Area (km^2)	Peri-Meter (km)	Stream Number of Different Orders								Order Wise Total Stream Length (km)							
			1	2	3	4	5	6	7	Total	1	2	3	4	5	6	7	Total
1	431.08	133.64	763	205	39	11	3	2	1	1024	429.50	148.45	81.169	67.73	28.67	24.87	1.9	782.29
2	664.90	144.01	1099	280	70	16	3	1		1469	619.94	241.06	160.17	82.68	19.99	53.64		1177.48
River Basin	1095.98	165.82	1862	485	109	27	6	2	1	2492	1049.44	389.51	241.339	150.41	48.66	78.51	1.9	1959.77

Table 2(b): Linear Aspects of Upper Bearch River Sub-Basins

Basin/ Sub-Basin	Mean Stream Length (km)								Stream Length Ratio (R_L)							Bifurcation Ratio (R_b)						
	1	2	3	4	5	6	7	Total	2/1	3/2	4/3	5/4	6/5	7/6	Mean R_L	R_b 1	R_b 2	R_b 3	R_b 4	R_b 5	R_b 6	Mean R_b
1	0.57	0.72	2.08	6.16	9.56	12.44	1.9	33.42	1.29	2.87	2.96	1.55	1.30	0.15	1.69	3.72	5.26	3.55	3.67	1.5	2.0	3.28
2	0.56	0.86	2.29	5.17	6.66	53.64		69.18	1.53	2.66	2.26	1.29	8.05		3.16	3.93	4.00	4.38	5.33	3.0		4.13
River Basin	0.56	0.80	2.21	5.57	8.11	39.26	1.9	58.42	1.42	2.76	2.52	1.46	4.84	0.05	2.17	3.84	4.45	4.04	4.50	3.0	2.0	3.64

Table 3: Aerial Aspects of Upper Bearch River Sub-Basins

Basin/ Sub-Basin	Form Factor	Circulatory Ratio	Elongation Ratio	Drainage Density (km/km^2)	Stream Frequency	Constant of Channel Maintenance	Length of Overland Flow (km^2/km)
1	0.18	0.30	0.47	1.84	2.38	0.551	0.276
2	0.15	0.40	0.44	1.77	2.21	0.565	0.282
River Basin	0.23	0.50	0.54	1.79	2.27	0.559	0.280

Table 4: Relief Aspects of Upper Bearch River Sub-Basins

Basin/ Sub-Basin	Elevation (m)		Relief (m)	Relief Ratio	Ruggedness Number
	Max.	Min.			
Sub-basin-1	672	454	218	0.005	0.40
Sub-basin-2	920	469	451	0.008	0.80
River Basin	920	454	466	0.0068	0.83

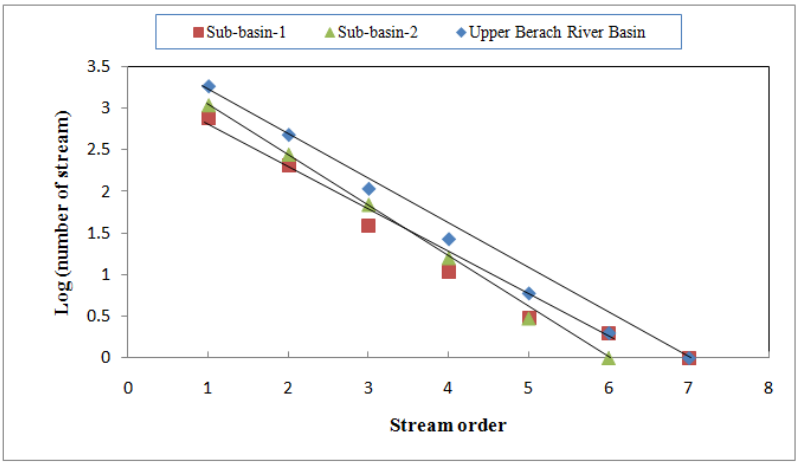

Figure 2: Relationship between Log (Number of Stream) and Stream Order

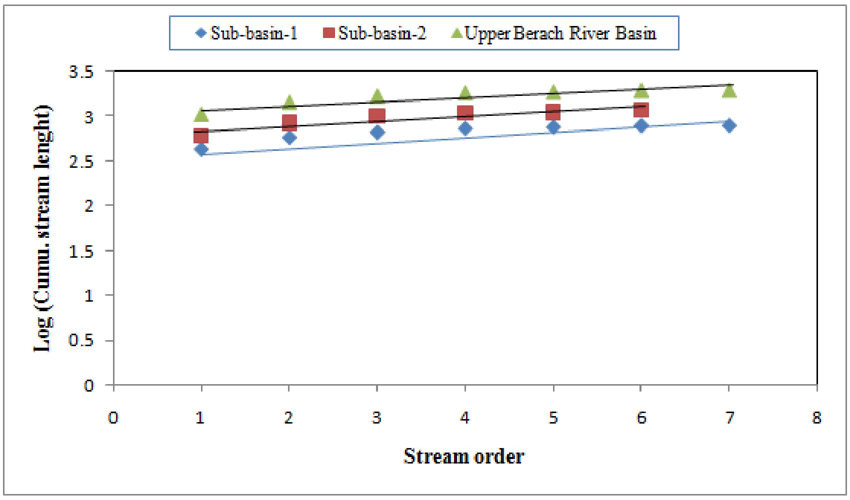

Figure 3: Relationship between Log (comu. Stream Length) and Stream Order